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# Evaluation of Three Physiological Traits for Selecting Drought Resistant Wheat Genotypes

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## ABSTRACT

**Physiological traits are receiving increasing attention as screening tools for drought resistance. Two field experiments were conducted in 1998 at the Experimental Station of College of Agriculture, Shiraz University at Badjgah, to evaluate the effectiveness of leaf water potential, leaf osmotic potential and canopy temperature in screening resistant bread wheat (*Triticum aestivum* L.) genotypes. Nine wheat cultivars consisting of drought resistant, intermediate and susceptible genotypes were grown in two randomized complete block designs with three replications. The experiments only differed with respect to their irrigation regimes. Leaf water potentials and leaf osmotic potentials at three developmental stages -stem elongation, booting and flowering - under water stress conditions, and canopy temperature in non-stress conditions could discriminate between resistant and susceptible cultivars. Although the drought susceptibility index could partly discriminate between resistant and susceptible cultivars, it was not evaluated as a reliable index. The linear regression of grain yield on each trait was determined. The linear regressions of grain yield on leaf water potential; leaf osmotic potential and canopy temperature confirmed the above results.**


**Keywords**: *Triticum aestivum,* Leaf water potential, Osmotic potential, Turgor potential, Canopy temperature.

## INTRODUCTION

Soil water deficit depresses agricultural crop yield in many parts of the world. Plant breeders search for effective and repeatable criteria to screen germplasms, for drought resistance in segregating populations. Plant breeders have used selected physiological parameters that are important in the plant-water relations of bread wheat (*Triticum aestivum* L.) under stress conditions. Levitt (1972), and Matin *et al.* (1989) reported that total water potentials of plant tissue are different between drought-resistant and drought-susceptible genotypes. Moustafa et *al.* (1996) used leaf water and osmotic potentials to differentiate apparent drought tolerance among wheat cultivars. They reported that the leaf water potentials of the water-stressed treatment were much lower than those of the well-watered control. They also concluded that osmotic adjustment did not contribute to the differences between cultivars in response to water stress. However, Blume (1989) suggested that induced osmotic adjustment under drought stress might be an important component of drought resistance in barley growth. Neumann (1995) rejected the notation that a stress-induced reduction in cellular turgor pressure is a primer cause of growth inhibition. Hoffman and Jobes (1978) reported that the relationship between crop yield and total leaf water potentials was negative and linear.

Canopy temperature is another criterion, which has been considered effective in screening wheat (Blum *et al.*, 1982; Pinter *et al.* 1990; Golestani Araghi and Assad, 1998)

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and pearl millet (Singh and Kanemasu, 1983) genotypes resistant to drought. Plant breeders have used selected physiological parameters that play a role in the plant-water relations of wheat under stress conditions (Keim and Kronstad, 1981; Jaradat and Konzak, 1983; Seropian and Planchon, 1984; Turner, 1986 a, b; Blum, 1989; Matin *et al.* 1989). The objectives of this study were to evaluate leaf water potential, leaf osmotic potential, and canopy temperature in differentiating wheat cultivars for drought resistance and to find their relationships with grain yield.

## MATERIALS AND METHODS

Two field experiments were conducted in 1998 at the Experimental Station of College of Agriculture, Shiraz University, at Badjgah (Iran). Nine hexaploid wheat cultivars were used in both experiments. According to the ranking proposed by the Seed and Plant Improvement Institute and later approved by Golestani Araghi and Assad (1998), three drought resistant cultivars (Omid, Roshan, and Kal-Haydary), three intermediate (Bayat, Niknejad, and M-75-5), and three drought sensitive ones (Falat, Darab, and Azadi Cross) cultivars were used. Cultivars were planted on 6$^{th}$ November 1998 in two experiments using randomized complete block designs each with three replications on a clay loam soil. Each plot consisted of eight 5m rows with the rows 25cm apart. The four middle rows were used for grain yield determination, and data were recorded on the basis of 10 randomized selected plants in the second and seventh rows. Fertilizer was applied at the rate of 80 Kg/ha N and 70 Kg/ha $P_2O_5$. Crops received one half of N in urea form and total amount of $P_2O_5$ at planting, while the remaining N was applied at tillering stage.

The two experiments differed with respect to their irrigation regimes. The non-stress experiment received water when 40±5 mm evaporation occurred from pan class A, while the stress experiment was not irrigated after plant establishment. The soil moisture status in the non-stress experiment was measured with a neutron probe (Troxler Model 2651). The effective rainfall during 1998-9 and total irrigation for each experiment are given in Table 1.

*Leaf water potential* ($\psi_w$) was measured using a PMS pressure bomb (PMS Instrument Co., Corvallis, OR) at stem elongation, booting and flowering plant developmental stages based on Zeidak`s Code in both experiments. The youngest fully expanded leaf was detached and placed rapidly in a sample chamber and the pressure was recorded. For each developmental stage three randomly selected plants were used. Measurements were completed between 13.00 and 15.00 hours. To measure *osmotic potential* ($\psi_s$), the youngest fully expanded leaf of each of 10 randomly selected plants was used for each developmental stage. Leaves were placed in plastic bags and rapidly packed in

**Table 1.** Precipitation distribution and total irrigation for each experiment.

| Month | Effective Rainfall | Irrigation (mm) | |
|---|---|---|---|
| | | Non-stress | Stress |
| November | 19.7 | 140 | 140 |
| December | 126.8 | - | - |
| January | 26.1 | - | - |
| February | 165.8 | - | - |
| March | 60.4 | - | - |
| April | 50.7 | - | - |
| May | 5.0 | 200 | - |
| June | - | 100 | - |
| Total | 454.5 | 440 | 140 |
| Total water used | | 894.5 | 594.5 |





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a box in order to avoid water-loss as vapor from the sample and maintained at -15°C for five hours. The frozen samples were then thawed for approximately 30 minutes and the freezing point (T) of collected saps was measured using a digital thermometer (Model ET - 2001). The osmotic potential then was calculated (Kramer, 1995) by:

$\psi_s = (-T / 1.86) \times 2.27$

*The canopy temperature* ($T_C$) of each plot was measured at three development al stages at 13.00 to 15.00 hours in both experiments using an infrared thermometer (Kane-May Model Infratrace 800). The instrument was pointed down at three random points in each plot and held at an oblique angle to the canopy surface to minimize the influence of soil exposure. The *drought susceptibility index* (S) was also determined by the following equation (Fischer and Mourer, 1978):

$S = [1-(\bar{y}_D / \bar{y}_p)] / D$

Where $\bar{y}_D$ and $\bar{y}_p$, are the grain yield of each cultivar at stress and non-stress conditions respectively, and $D = 1- (\bar{Y}_D / \bar{Y}_P)$. $\bar{Y}_D$ and $\bar{Y}_P$ are the mean yield of all the cultivars under stress and non-stress conditions. Analysis of variance in all the measurements was conducted by Statistical Analysis System (SAS, 1985). Means were separated using the least significant difference (LSD). The regression of grain yield on each physiological index was also determined. To compare the effects of stress and non-stress, and cultivars by moisture conditions interaction, a combined analysis of variance was used.

## RESULTS AND DISCUSSION

The mean grain yield and some related components for both experiments are showed in Table 2. Cultivars did not differ significantly in respect to grain yield under non-stress conditions, however, the differences were significant under stress conditions ($p<0.01$). This emphasized the different responses of cultivars to drought conditions. All of the characters in Table 2 were reduced under stress conditions, but the reductions in spike length were not significant. Susceptible cultivars on average showed higher drought susceptibility indices than intermediate and resistant cultivars, however there was some misclassification, especially in respect to intermediate and resistant cultivars.

The leaf water potentials ($\psi_w$) of cultivars at three developmental stages are given in Table 3. The $\psi_w$ values decreased with maturation in both environments and cultivars showed significant differences in all stages ($p<0.01$). Table 3 indicates that leaf water potential apparently discriminated between drought resistant, intermediate, and susceptible cultivars at the three stages in both environmental conditions. Drought resistant cultivars showed lower $\psi_w$ values as compared to sensitive ones. This is in agreement with the results obtained by others (Barlow *et al.*, 1980; Keim and Kronstad, 1981; Matin *et al.* 1989; Entz and Flower, 1990; Moustafa *et al.*, 1996). The linear relationship between $\psi_w$ and grain yield was significant under stress condition only (Table 4). Although $\psi_w$ in all stages and conditions could classify cultivars in respect to drought resistance, however, Table 3 shows that $\psi_w$ values in stress conditions were more effective. The results obtained from linear regressions also confirmed these results.

The leaf osmotic potential ($\psi_s$) of cultivars at different developmental stages in stress and non-stress conditions are given in Table 3. The trend of variation in $\psi_s$ values in different developmental stages was similar to that of $\psi_w$. Cultivars were significantly different with regard to values in all stages, in both environments ($p<0.01$). The $\psi_s$ values of drought resistant cultivars were, on average, lower than those of drought susceptible ones in all conditions, indicating that $\psi_s$ was an effective technique in screening resistant genotypes. Other investigators (Grumet *et al.*, 1987; Blume, 1989; Musick *et al.*, 1994) also reported that drought resistant cultivars had lower $\psi_s$ values as compared to





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**Table 2.** Mean grain yield, some related yield components, and drought susceptibility index of nine wheat cultivars under stress an non-stress conditions.

| Irrigation regim | Cultivars | Grain yield($g/m^2$) | Total dry matter($g/m^2$) | Harvest index(%) | No. of Seed /spike | Awn length (mm) | Spike length(mm) | 1000 seeds weight(g) | Flag leaf area ($cm^2$) | Drought Susceptibility index |
|---|---|---|---|---|---|---|---|---|---|---|
| Non-stress | Kal-Haydary | 505.6 a | 1673.8 a | 30.2 bc | 27.9 d | 58.5 b | 106.0 b | 51.0 ab | 14.9 d | 0.757 |
| | Roshan | 658.1 a | 2037.1 a | 32.4 abc | 50.4 bc | 5.5 c | 106.7 b | 46.6 abc | 25.5 ab | 0.910 |
| | Omid | 593.9 a | 2141.8 a | 27.8 c | 59.5 ab | 79.4 a | 132.0 a | 39.6 abc | 27.5 a | 1.009 |
| | Bayat | 561.4 a | 1674.4 a | 33.3 ab | 53.9 bc | 65.8 b | 93.9 bcd | 33.2 c | 22.6 abc | 0.843 |
| | Niknejad | 663.1 a | 1936.8 a | 34.2 ab | 52.7 bc | 61.5 b | 97.8 bcd | 36.0 c | 17.5 cd | 0.895 |
| | M75-5 | 659.1 a | 1851.6 a | 35.6 a | 48.7 bc | 64.9 b | 103.1 bc | 51.9 a | 22.9 abc | 0.946 |
| | Darab | 566.0 a | 1717.6 a | 32.9 ab | 46.2 bc | 63.1 b | 87.3 d | 35.4 c | 21.3 bc | 1.096 |
| | Falat | 685.6 a | 1864.0 a | 36.8 a | 44.8 c | 75.3 a | 91.0 cd | 39.2 abc | 22.3 abc | 1.086 |
| | Azadi-Cross | 609.3 a | 1761.9 a | 34.6 ab | 73.2 a | 79.7 a | 97.7 bcd | 36.7 bc | 19.6 bcd | 1.108 |
| CV % | | 13.22 | 11.51 | 5.97 | 10.95 | 6.24 | 5.48 | 15.05 | 16.19 | |
| Stress | Kal-Haydary | 275.8 ab | 972.6 a | 28.7 ab | 28.4 cd | 56.7 c | 112.8 a | 39.6 a | 7.5 d | |
| | Roshan | 298.6 ab | 1026.7 a | 29.2 a | 41.1 bcd | 8.0 c | 98.7 a | 34.6 ab | 13.5 abc | |
| | Omid | 234.4 bc | 1056.7 a | 21.9 cd | 39.3 bcd | 74.7 a | 127.6 a | 33.1 ab | 14.2 ab | |
| | Bayat | 277.5 ab | 1160.2 a | 23.5 bcd | 49.3 ab | 66.9 ab | 93.2 a | 26.3 cd | 11.2 bcd | |
| | Niknejad | 306.8 a | 1128.5 a | 27.5 abc | 50.5 ab | 65.4 bc | 100.6 a | 28.3 bcd | 13.1 abc | |
| | M75-5 | 284.9 ab | 991.1 a | 28.1 ab | 48.4 ab | 68.5 ab | 106.0 a | 30.2 bc | 13.2 abc | |
| | Darab | 193.8 c | 819.9 a | 23.4 bcd | 37.9 bcd | 56.7 c | 83.2 a | 28.3 bcd | 8.8 cd | |
| | Falat | 238.8 abc | 909.4 a | 25.6 abcd | 41.7 bc | 71.0 ab | 90.3 a | 29.6 bc | 13.4 abc | |
| | Azadi-Cross | 204.0 c | 936.2 a | 21.5 d | 56.9 a | 73.8 ab | 94.9 a | 22.5 d | 17.1 a | |
| | CV % | 15.69 | 15.24 | 9.25 | 12.72 | 6.21 | 25.26 | 9.24 | 16.97 | |
| Stress vs. non-stress | | ** | ** | ** | * | NS | NS | ** | ** | |
| Cultivars & moisture Cndition interaction | | NS | NS | * * | * | NS | NS | NS | * | |
| | CV % | 14.71 | 12.99 | 7.43 | 11.77 | 6.23 | 17.83 | 13.45 | 16.97 | |

NS: Nonsignificant

*, ** Significant at 0.05 and 0.01, respectively.

Means followed by the same letter in each column in each environment are not significantly different (LSD test)

**Table 3.** Leaf water potential, leaf osmatic potential and canopy temperature of nine wheat cultivars in different developmental stages, in non-stress and stress conditions.

| Irrigation regimes | Genotype | Leaf water potential (MPa) | | | Leaf osmatic potential (MPa) | | | Canopy temperature (°C) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Stem elongation | Booting | Flowering | Stem elongation | Booting | Flowering | Stem elongation | Booting | Flowering |
| Non-stress | Kal-Haydary | -0.60 c | -1.95 d | -2.10 d | -2.4 d | -3.03 f | -3.66 f | 20.0 a | 37.7 a | 42.0 a |
| | Roshan | -0.57 bc | -1.74 d | -1.93 d | -2.17 d | -2.20 d | -2.25 d | 21.8 a | 34.7 ab | 41.3 a |
| | Omid | -0.43 abc | -1.26 c | -1.41 abc | -0.78 ab | -1.90 c | -2.02 cd | 20.0 a | 35.0 a | 42.3 a |
| | Bayat | -0.58 bc | -1.14 c | -1.52 c | -2.11 cd | -2.29 de | -2.35 de | 21.8 a | 32.7 abc | 36.3 b |
| | Niknejad | -0.21 a | -1.16 c | -1.53 c | -1.9 cd | -2.26 de | -2.35 de | 19.7 a | 32.0 abcd | 37.0 b |
| | M75-5 | -0.31 abc | -1.05 bc | -1.46 bc | -1.46 bc | -2.42 e | -2.69 e | 19.3 a | 32.0 abcd | 34.4 bc |
| | Darab | -0.27 ab | -0.49 a | -1.06 a | -0.79 ab | -0.86 a | -1.54 ab | 16.5 a | 27.3 cd | 33.6 bc |
| | Falat | -0.20 a | -0.69 ab | -1.23 abc | -0.95 ab | -1.42 b | -1.65 bc | 18.7 a | 28.7 bcd | 31.0 c |
| | Azadi-Cross | -0.30 abc | -0.60 a | -1.09 ab | -0.52 a | -0.74 a | -1.19 a | 16.2 a | 26.3 d | 26.0 d |
| CV % | | - 33.72 | - 14.55 | - 10.74 | - 20.00 | - 4.32 | - 7.48 | 12.67 | 8.01 | 16.19 |
| Stress | Kal-Haydary | -2.15 e | -3.13 e | -4.19 d | -3.05 e | -3.73 b | -4.64 e | 35.3 a | 46.0 a | 54.5 a |
| | Roshan | -2.61 e | -3.06 e | -4.15 d | -2.95 e | -3.60 b | -4.43 d | 35.3 a | 43.1 ab | 53.2 ab |
| | Omid | -1.85 de | -2.87 de | -3.97 d | -2.70 de | -3.51 b | -4.38 d | 25.3 b | 44.6 a | 52.0 bc |
| | Bayat | -1.47 cd | -2.59 cd | -3.56 c | -2.51 cd | -3.26 ab | -4.13 c | 22.7 b | 42.3 ab | 53.0 ab |
| | Niknejad | -1.44 cd | -2.58 cd | -3.54 c | -2.28 bc | -3.21 ab | -4.02 c | 24.3 b | 37.3 cde | 52.1 bc |
| | M75-5 | -1.05 bc | -2.33 bc | -3.58 c | -2.52 cd | -3.25 ab | -4.04 c | 33.6 a | 40.30 abc | 51.9 bc |
| | Darab | -0.90 ab | -2.18 ab | -3.16 ab | -1.89 a | -2.76 a | -3.46 a | 27.3 ab | 35.0 de | 50.9 c |
| | Falat | -1.15 bc | -2.34 bc | -3.36 bc | -1.99 ab | -2.76 a | -3.62 b | 25.3 b | 38.3 bcd | 51.3 bc |
| | Azadi-Cross | -0.46 a | -1.87 a | -2.90 a | -1.65 a | -2.82 a | -3.42 a | 25.3 b | 32.8 e | 51.8 bc |
| CV % | | - 13.77 | - 6.27 | - 3.21 | - 6.46 | - 7.23 | - 1.59 | 11.90 | 5.12 | 1.60 |
| Stress vs. non-stress | | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| CV % | | - 18.42 | - 8.80 | -5.47 | - 12.09 | - 6.81 | - 4.01 | 12.36 | 6.45 | 3.12 |

*, ** Significant at 0.05 and 0.01 level, respectively. NS: Non significant
Means followed by the same letter in each column in each environment are not significantly different (LSD least significant difference).

**Table 4.** The significant regressions of grain yield on four physiological traits at three developmental stages, under stress and non- stress conditions.

| Physiological trait | Developmental stage | Non-stress | | | Stress | | |
|---|---|---|---|---|---|---|---|
| | | Regression equation | $R^2$ (n) | P | Regression equation | $R^2$ (n) | P |
| Leaf water potential ($\psi_w$) | Stem elongation | | | NS | Y= -53.322 x + 182.89 | 0.156(27) | < 0.05 |
| | Booting | | | NS | Y=- 70.267 x + 77.93 | 0.126(27) | < 0.05 |
| | Flowering | | | NS | | | NS |
| Leaf osmotic potential ($\psi_s$) | Stem elongation | | | NS | Y= -77.347 x + 72.04 | 0.245(27) | < 0.01 |
| | Booting | | | NS | Y= -91 x – 34.99 | 0.244(27) | < 0.01 |
| | Flowering | | | NS | Y= -83.537 x – 78.29 | 0.224(27) | < 0.05 |
| Canopy Temperature | Stem elongation | Y= 9.89 x + 418.37 | 0.156 (27) | <0.05 | | | NS |
| | Booting | | | NS | | | NS |
| | Flowering | | | NS | | | NS |

NS=Non-significant

susceptible ones. Table 3 indicates that $\psi_s$ values in stress conditions could classify genotypes better compared with non-stress condition. The regressions of grain yield on $\psi_s$ were significant under stress condition (Table 4). This indicated that leaf osmotic potential might be a good trait for selecting wheat genotypes resistant to draught in stress conditions.

The differences in the canopy temperature ($T_c$) of cultivars were highly significant in both moisture conditions ($p<0.01$) and growth stages, except stem-elongation in non-stress conditions (Table 3). This exception may be due to similar transpiration activity of all cultivars under well-watered environmental conditions. Except for stem elongation in non-stress condition, the linear regressions of grain yield on canopy temperature were not significant in other cases (Table 4). The canopy temperature of cultivars in flowering, under non-stress conditions, could help discriminate between resistant and susceptible cultivars better than at other stages. Pinter *et al.* (1990) and Golestani Araghi and Assad (1998) also reported that ($T_a$-$T_c$) is a valuable technique in screening drought resistant genotypes.

## CONCLUSION

This study showed that leaf water potentials and leaf osmotic potentials of wheat plants at the three developmental stages (stem elongation, booting, and flowering) under water stress conditions, and canopy temperature in non-stress conditions were the best criteria for screening drought resistant genotypes. Although the drought susceptibility index could partly discriminate between resistant and susceptible cultivars, it was not evaluated as a consistent reliable criterion alone. For more reliability of results use of more genotypes and seasons are recommended.

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## ارزیابی سه معیار فیزیولوژیک جهت گزینش ژنوتیپ‌های گندم مقاوم به خشکی

**ر. امیری فهلیانی و م. ت. آساد**

## چکیده

صفات فیزیولوژیک به عنوان ابزاری جهت تشخیص ژنوتیپ‌های مقاوم به خشکی مورد توجه روز افزون قرار گرفته است. دو آزمایش در سال ۱۳۷۷ در ایستگاه پژوهشی دانشکده کشاورزی، دانشگاه شیراز جهت ارزیابی تاثیر پتانسیل آب برگ، پتانسیل اسمزی برگ، و درجه حرارت سایه انداز بر تشخیص ژنوتیپ‌های مقاوم گندم (Triticum aestivum L.) انجام گرفت. نه رقم گندم مقاوم، نیمه مقاوم و حساس به خشکی در دو طرح جداگانه بلوک‌های کامل تصادفی به کار برده شد. یکی از آزمایش‌ها تحت شرایط مطلوب و دیگری تحت تنش آبی قرار گرفت. صفات فیزیولوژیک مزبور در سه مرحله رشد (طویل شدن ساقه، غلاف رفتن و گل دهی) گیاه اندازه‌گیری شد. رگرسیون شاخص حساسیت به خشکی بر هر کدام از صفات نیز تعیین شد. پتانسیل آب برگ و پتانسیل اسمزی برگ در هر سه مرحله رشد تحت شرایط آبی و درجه حرارت سایه انداز تحت شرایط مطلوب در تشخیص ژنوتیپ‌های حساس و مقاوم موثر بودند. هر چند شاخص حساسیت به خشکی تا حدودی در گروه بندی ارقام به حساس و مقاوم موثر بود، ولی معیار قابل اعتمادی تشخیص داده نشد. رگرسیون خطی شاخص حساسیت به خشکی بر تمام معیارها تعیین شد.





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